EVALUATION OF ADVANCED GEOPOTENTIAL MODELS FOR OPERATIONAL ORBIT DETERMINATION*

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ABSTRACT

To meet future orbit determination accuracy requirements for different National Aeronautics and Space Administration (NASA) projects, analyses are performed using Tracking and Data Relay Satellite System (TDRSS) tracking measurements and orbit determination improvements in areas such as the modeling of the Earth's gravitational field. Current operational requirements are satisfied using the Goddard Earth Model-9 (GEM-9) geopotential model with the harmonic expansion truncated at order and degree 21 (21-by-21). This study evaluates the performance of 36-by-36 geopotential models, such as the GEM-10B and Preliminary Goddard Solution-3117 (PGS-3117) models.

The Earth Radiation Budget Satellite (ERBS) and Landsat-5 are the spacecraft considered in this study. Series of orbit determination solutions are generated for 34-hour arcs with 10-hour overlaps using the batch weighted-least-squares method. Orbit determination consistency is evaluated by comparing ephemerides during the 10-hour overlap periods. The sensitivity of the solutions to variations in the tracking data distribution is also considered. The principal source of tracking data is TDRSS, but Ground Spaceflight Tracking and Data Network (GSTDN) data are also considered.

The orbit consistencies are improved, relative to GEM-9 (21-by-21) results, by an average of 7 meters out of 34 meters for ERBS and 7 meters out of 56 meters for Landsat-5. The detailed results and conclusions of the comparative evaluation of the effects of geopotential models on the accuracy of orbit determination results are presented.

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1. INTRODUCTION

The Tracking and Data Relay Satellite System (TDRSS) has been providing routine operational tracking support to TDRSS user satellites with a single relay spacecraft, Tracking and Data Relay Satellite-East (TDRS-E), for approximately 4 years. The completed TDRSS will comprise two operational relay satellites and one in-orbit spare. The operational satellites will be located at 41 degrees west longitude and 171 degrees west longitude and will communicate with the White Sands Ground Terminal (WSGT) at White Sands, New Mexico. Selected TDRSS users receive some tracking support from the Ground Spaceflight Tracking and Data Network (GSTDN). While GSTDN provides approximately 15-percent visibility coverage, TDRSS can provide 85-percent to 100-percent visibility coverage.

The Bilateration Ranging Transponder System (BRTS) is used to provide tracking measurements for the relay spacecraft. BRTS is a system of four ground-based unmanned facilities that contain transponders similar to those flown on user spacecraft. The positions of the BRTS transponders are known so that ranging information can be used to determine the orbits of the TDRSs. The BRTS facilities are located at WSGT; Ascension Island; American Samoa; and Alice Springs, Australia. TDRS-E and TDRS-Spare (TDRS-S) will be supported by the BRTS transponders at WSGT and Ascension Island, while TDRS-West (TDRS-W) will be supported by the BRTS transponders at Alice Springs, American Samoa, and WSGT.

While orbit determination requirements for currently operational spacecraft missions are satisfied by the orbit determination methods currently in place, meeting the more stringent definitive and predictive accuracy requirements for future missions requires an ongoing effort to improve orbit determination methods in such areas as force modeling, geophysical modeling, observation modeling, observation correction, estimation methods, orbit propagation, and numerical methods. The gravitational forces of the nonspherical Earth are the largest forces perturbing the orbits of low Earth-orbiting spacecraft. Continued improvement in the modeling of the gravitational geopotential is crucial to future improvements in orbit determination accuracy. This paper reports on evaluations of the effectiveness of certain improved geopotential models when applied to orbit determination in an operational environment.

The geopotential models used are supplied by the Geodynamics Branch at the Goddard Space Flight Center (GSFC). The Goddard Earth Model-9 (GEM-9) (Reference 1) is a pre-Laser Dynamics Satellite (LAGEOS) model determined solely from observations of orbiting spacecraft and containing harmonic expansion terms up to the 30th degree and order. The geopotential model used at GSFC's Flight Dynamics Facility (FDF) for routine operational orbit determination of low Earth-orbiting spacecraft is the truncation of GEM-9 at 21st order and degree, referred to as GEM-9 (21 x 21). For TDRS orbit determination, the GEM-9 (8 x 8) model is used, since the higher-degree terms have been found to have a negligible effect for geosynchronous orbits. The GEM-10B model (Reference 2) is a 36-by-36 model based on spacecraft observations and surface gravimetry. The GEM-L2A model is a modification of the GEM-L2 model (Reference 3), a 30-by-30 "satellite only" model which, because of its extensive use of data from the LAGEOS spacecraft, is considered to be very accurate at long wavelengths. The GEM-L2A (8 x 8) model has been used for some of the TDRS-E orbit solutions in the studies reported in this paper. The Preliminary Goddard Solution-3117 (PGS-3117) model is a preliminary version of the model that has been published as GEM-T1 (Reference 4). GEM-T1 is a 36-by-36 "satellite only" model developed in support of the upcoming Topography Experiment (TOPEX) mission.

Section 2 of this paper describes the orbit determination methods utilized and the methods of evaluating geopotentials using orbit determination results. Section 3 discusses the results of the orbit determination studies, and Section 4 presents the conclusions.

2. METHODS OF ORBIT DETERMINATION AND GEOPOTENTIAL MODEL EVALUATION

The methods of orbit determination and geopotential model evaluation used in this study are described in Sections 2.1 and 2.2, respectively.

2.1 ORBIT DETERMINATION METHODOLOGY

The orbit determination methods used in this study are basically those used for operational orbit determination at GSFC. The batch weighted-least-squares algorithm implemented in the Goddard Trajectory Determination System (GTDS) (Reference 5) solves for the set of orbital elements and other parameters that minimizes the difference between observed and calculated values of selected tracking data over a solution arc. Estimated parameters include the spacecraft state at epoch and, optionally, one or more free parameters of the force model and/or the observation model. In GTDS, several different force models, as well as a selection of orbit propagators, numerical integrators, observation correction models, and dynamic observation editing options are available. The general options used for the studies described in this paper are summarized in Table 1.

The first step in orbit determination with GTDS is use of the Differential Correction (DC) Program to find the solution parameters at a designated epoch that best fit the tracking measurements using the batch weighted-least-squares method. The Ephemeris Generation (EPHEM) Program regenerates the ephemerides from the epoch solution. In this study, analysis is performed only with definitive ephemerides that are generated over the tracking data span.

To evaluate the orbit determination consistency achievable with a particular choice of options, a series of seven or eight daily 34-hour solutions is performed with 10-hour overlaps between successive arcs. The Ephemeris Comparison (COMPARE) Program is used to determine the maximum position differences between the definitive ephemerides for successive solutions in the 10-hour overlap time period. These six or seven overlap comparisons are a measure of the orbit determination consistency.

Table 1. Parameters and Options for User and Relay Spacecraft Orbit Determination

PARAMETER OR OPTION	VALUE OF PARAMETER OR OPTION CHOSEN	
	USER	TDRS
INTEGRATION TYPE	FIXED-STEP COWELL	FIXED-STEP COWELL
COORDINATE SYSTEM OF INTEGRATION	MEAN OF 1950.0	MEAN OF 1950.0
INTEGRATION STEP SIZE (SECONDS)	60.0	600.0
GEOPOTENTIAL MODELS	GEM-9 (21 x 21) GEM-10B (36 x 36) PGS-3117 (36 x 36)	GEM-9 (8 x 8) GEM-L2A (8 x 8)
ATMOSPHERIC DENSITY MODEL	HARRIS-PRIESTER (F = 75)	N/A
SOLAR AND LUNAR EPHEMERIDES	DE-118[a]	DE-118[a]
SOLAR REFLECTIVITY COEFFICIENT (C_R)	1.2	ESTIMATED
COEFFICIENT OF DRAG (C_D)	2.2	N/A
ESTIMATED PARAMETERS	STATE, DRAG SCALING PARAMETER (ρ_I)	STATE, SOLAR REFLECTIVITY COEFFICIENT (C_R)
DIFFERENTIAL CORRECTION (DC) CONVERGENCE PARAMETER	0.005	0.005
DC EDITING	3σ	3σ
IONOSPHERIC REFRACTION CORRECTION	YES (BENT MODEL)	YES (BENT MODEL)
TROPOSPHERIC REFRACTION CORRECTION	YES	YES
ANTENNA MOUNT CORRECTION	NO	NO
TRACKING DATA	TDRSS OR TDRSS + GSTDN	BRTS

[a] DE-118 INDICATES JET PROPULSION LABORATORY (JPL) DEVELOPMENT EPHEMERIS 118.

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When more than one set of orbit determination options is under study, the entire series is repeated with each of the different sets of options. In addition, the COMPARE Program may be used to obtain the maximum position difference between corresponding ephemerides from different series. These parallel comparisons measure the total effect of the difference between two sets of options on the trajectories determined in two series of solutions.

The detailed results presented in this paper are from studies in which TDRS orbits, predetermined using only BRTS data, were input and remained fixed during the user spacecraft solution process. An alternative mode of orbit determination would solve for both user and relay spacecraft variables simultaneously, allowing the TDRSS tracking observations of the user to directly influence both orbits. While the latter mode offers certain operational benefits when only a single user spacecraft is under study, in the current operational environment, more accurate TDRS orbits are obtained in isolation from the greater uncertainties of the orbit determination of low Earth-orbiting users. Some of the geopotential modeling studies reported in this paper have been repeated in the simultaneous orbit determination mode, with results that are essentially the same as far as geopotential model evaluation is concerned (References 6 and 7).

2.2 GEOPOTENTIAL MODEL EVALUATION METHODOLOGY

The gravitational field of the nonspherical Earth is modeled in GTDS using the standard expansion in spherical harmonic functions (Reference 5), truncated at a fixed maximum degree and order. Different geopotential models correspond to different values of the harmonic expansion coefficients. The standard operational version of GTDS is only capable of including 21 degrees and orders. A special version of GTDS, called GATFITR, which can utilize up to 36 degrees and orders, was used for this study. GATFITR enables the use of the GEM-10B, PGS-3117, and GEM-T1 gravitational models.

With the TDRS orbit predetermined, it is possible to use a different geopotential model for user orbit determination. This is also possible with GATFITR in the simultaneous orbit determination mode. User orbit determination studies of the 36-by-36 models were sometimes repeated with two versions of the pregenerated TDRS-E orbits; one set of TDRS-E orbits was generated with GEM-9 (8 x 8) and another was generated with GEM-L2A (8 x 8). It was found that the geopotential used for TDRS orbit determination did not significantly affect the evaluation of the user geopotential. All studies in which GEM-9 (21 x 21) was employed for the user spacecraft used TDRS-E orbits corresponding to GEM-9 (8 x 8).

For some of the time periods studied, orbit determination was performed using only TDRSS tracking data, while for other time periods both TDRSS and GSTDN data were used. The former case is characteristic of operational orbit determination in the near future, while the latter is characteristic of the present.

For one of the Earth Radiation Budget Satellite (ERBS) evaluation periods, high TDRSS tracking coverage permitted good quality orbit determination with subsets of the available data. In this case, the series of solutions was repeated with two different tracking data distribution subsets in addition to the full data complement. Parallel consistency of solutions generated for corresponding arcs for the different data distributions was evaluated. High consistency of this type, as well as overlap consistency, is desirable for an effective geopotential model for operational orbit determination. For a given arc, the better the overall modeling, the less the solution should depend on the particular data used for orbit determination.

As a general rule, weighted root-mean-square (RMS) residuals and similar measures of goodness of fit are of limited utility in analytical comparisons of orbit determination solution results, because the dynamic residual editing process eliminates the most discrepant data from the statistics. Considerations of such measures in References 6, 7, and 8 support the conclusions presented in this paper but are not discussed here.

3. RESULTS AND DISCUSSION

The spacecraft arcs studied in this analysis are described in Section 3.1. The results of the Landsat-5 study are presented in Section 3.2, and the results of the ERBS studies with full data and with data distribution subsets are given in Sections 3.3 and 3.4, respectively.

3.1 SPACECRAFT ARCS STUDIED

The TDRSS user spacecraft chosen for this study were ERBS and Landsat-5. Their orbital characteristics and those of the TDRS-E are shown in Table 2.

Three intervals of approximately 1-week duration were selected for study. Table 3 defines these time periods and describes that two-way tracking data used for orbit determination in each period. Landsat-5 was studied in only

Table 2. Characteristics of TDRS-E and the TDRSS User Spacecraft

SPACECRAFT	SEMIMAJOR AXIS (kilometers)	ECCENTRICITY	INCLINATION (degrees)	PERIGEE HEIGHT (kilometers)
ERBS	6981	0.000275	57.00	598
LANDSAT-5	7078	0.000105	97.98	687
TDRS-E	42,166	0.000222	0.98	35,779

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Table 3. Tracking Data Periods, Pass Frequency, and Data Acceptance Statistics

SPACECRAFT	TIMESPAN (GMT)	AVERAGE NUMBER OF PASSES PER DAY		AVERAGE NUMBER OF ACCEPTED OBSERVATIONS PER 34-HOUR ARC			
				TDRSS		GSTDN	
		TDRSS	GSTDN	RANGE	DOPPLER	RANGE	DOPPLER
LANDSAT-5	16 JUNE 1986 AT 0^h TO 23 JUNE 1986 AT 10^h	6.2	1.6	455	461	78	131
ERBS	12 AUGUST 1985 AT 0^h TO 19 AUGUST 1985 AT 10^h	6.9	2.2	1046	1073	67	76
ERBS	16 JUNE 1986 AT 0^h TO 23 JUNE 1986 AT 10^h	6.3	2.2	909	906	82	100
ERBS	11 JANUARY 1987 AT 0^h TO 19 JANUARY 1987 AT 10^h	7.5	–	1203	1164	–	–

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one of these intervals, and ERBS was studied in all three. The pass counts given in Table 3 include every pass that was not completely flagged as invalid at the tracking station. The observation counts include only the measurements surviving the differential correction (DC) dynamic residual editing in the baseline DCs using GEM-9 (21 x 21) for the user spacecraft. The studies are referred to by the acronyms LAND86, ERBS85, ERBS86, and ERBS87, in the order given in Table 3.

3.2 LANDSAT-5 RESULTS

Three series of orbit determinations were performed in the LAND86 study. The geopotential models applied to the user spacecraft were the GEM-9 (21 x 21) and GEM-10B (36 x 36) models. Solutions for the latter model were obtained using TDRS-E orbits pregenerated with the GEM-9 (8 x 8) model and also with the GEM-L2A (8 x 8) model. Figure 1 gives a plot of the overlap

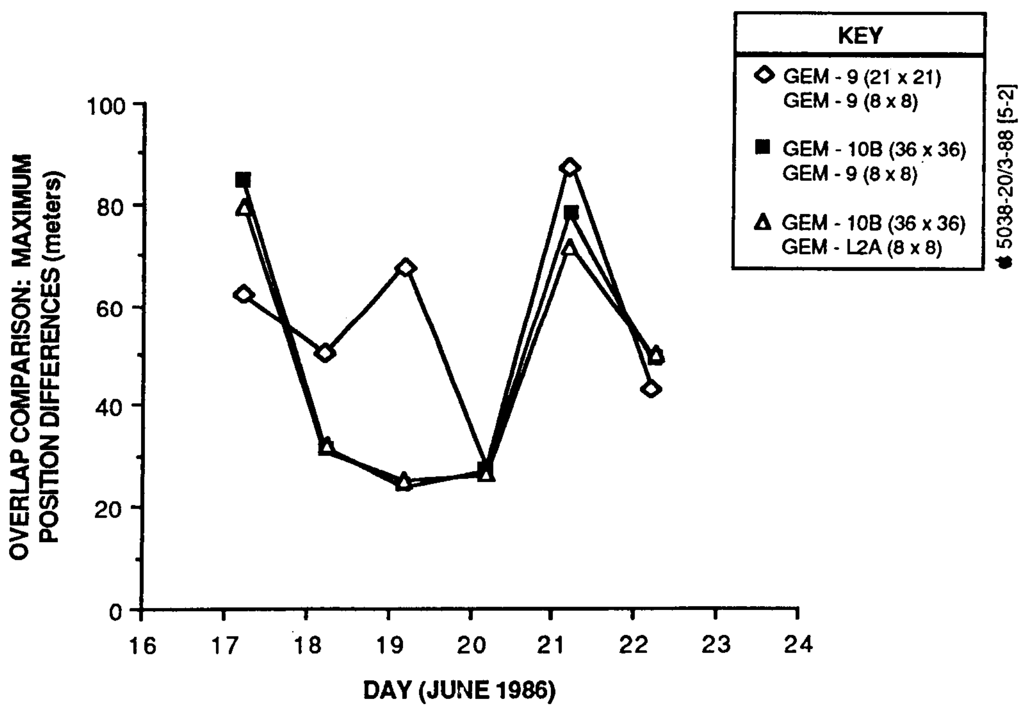

Figure 1. Maximum Overlap Comparisons for Landsat-5

comparisons as a function of the day in which the 10-hour overlap period occurs. Table 4 lists the respective means and standard deviations of these collections of six comparisons for all series. For LAND86, the improvement in the mean overlap comparison from using the GEM-10B geopotential model for Landsat-5 orbit determination is 7.2 ± 9.5 meters (mean and standard deviation in the mean of the differences between corresponding overlap comparisons). The differences between the user results obtained with the two different relay geopotential models are not significant.

Table 4. Statistical Summary of Overlap Comparisons for Series Using All Available Data

STUDY NAME	GEOPOTENTIAL MODELS		MAXIMUM OVERLAP COMPARISONS		
	USER	RELAY	NUMBER OF COMPARISONS	MEAN (METERS)	STANDARD DEVIATION (METERS)
LAND86	GEM-9 (21 x 21)	GEM-9 (8 x 8)	6	56.35	19.29
	GEM-10B (36 x 36)	GEM-9 (8 x 8)	6	49.17	24.17
	GEM-10B (36 x 36)	GEM-L2A (8 x 8)	6	47.51	22.08
ERBS85	GEM-9 (21 x 21)	GEM-9 (8 x 8)	6	21.24	10.30
	GEM-10B (36 x 36)	GEM-9 (8 x 8)	6	26.60	10.67
	GEM-10B (36 x 36)	GEM-L2A (8 x 8)	6	27.00	11.67
ERBS86	GEM-9 (21 x 21)	GEM-9 (8 x 8)	6	33.33	12.75
	GEM-10B (36 x 36)	GEM-9 (8 x 8)	6	24.20	11.62
	GEM-10B (36 x 36)	GEM-L2A (8 x 8)	6	23.79	12.06
ERBS87	GEM-9 (21 x 21)	GEM-9 (8 x 8)	6	47.82	6.13
	GEM-10B (36 x 36)	GEM-L2A (8 x 8)	6	29.34	10.62
	PGS-3117 (36 x 36)	GEM-L2A (8 x 8)	6	25.20	8.26
	PGS-3117 (36 x 36)	GEM-9 (8 x 8)	6	24.62	8.57
	GEM-9 (21 x 21)	GEM-9 (8 x 8)	7	46.77	6.23
	PGS-3117 (36 x 36)	GEM-9 (8 x 8)	7	22.64	8.72

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3.3 ERBS RESULTS WITH FULL DATA

For the ERBS85 and ERBS86 studies, the combinations of user and relay geopotential models for which series of solutions were obtained were the same as in the LAND86 study. The overlap comparisons from these series are plotted in Figure 2. The summary statistics of the overlap comparisons from each of these series are given in Table 4. The average improvements in overlap comparisons from using the GEM-10B (36 x 36) model instead of the GEM-9 (21 x 21) model are 9.1 ± 9.1 meters for ERBS86 and -5.4 ± 7.7 meters for ERBS85.

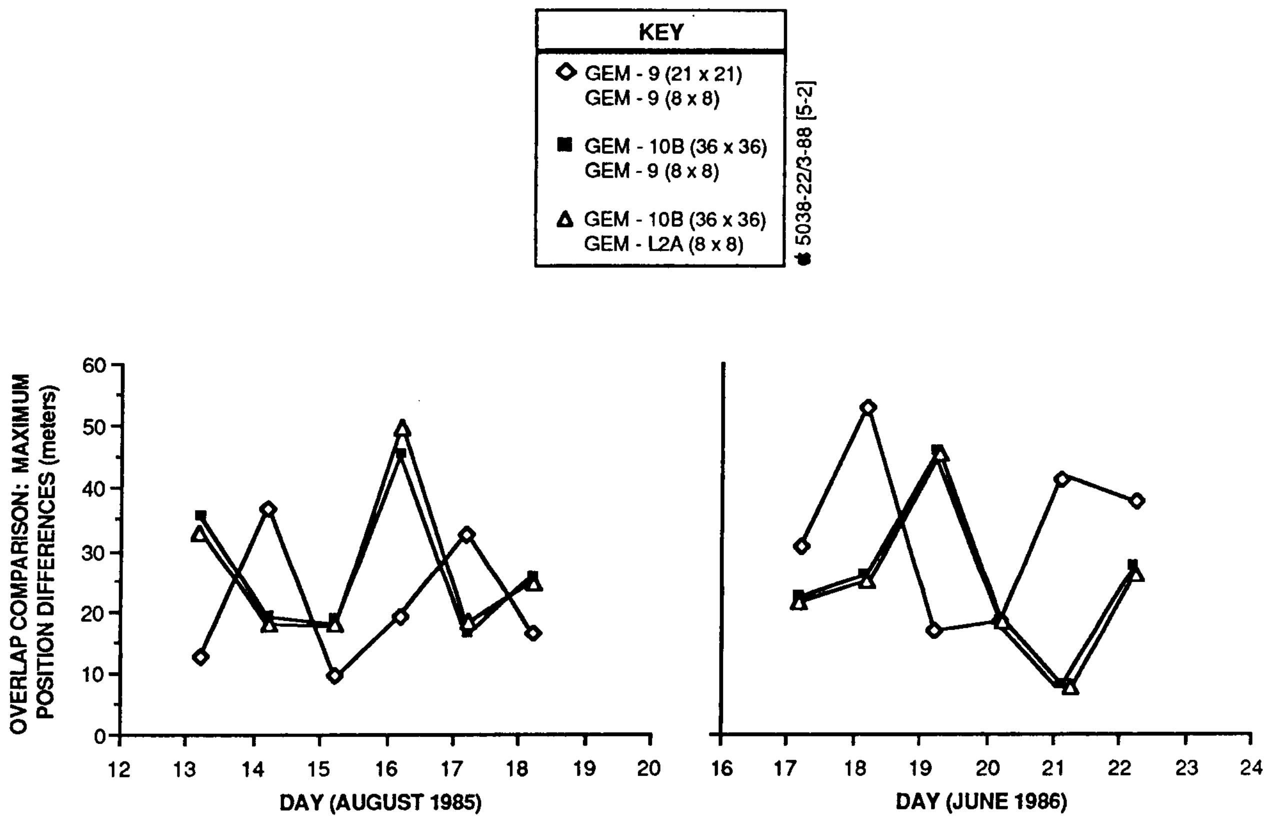

Figure 2. Maximum Overlap Comparisons for ERBS: ERBS85 and ERBS86 Studies

The combinations of user and relay geopotential models for which the ERBS87 orbit determination series were performed were given in Table 4 along with the overlap comparison summary statistics for the first 7 days of each series and for the full 8 days where applicable. Only the GEM-9 (21 x 21) and the PGS-3117 (36 x 36) user series that employ the GEM-9 (8 x 8) TDRS-E orbits were carried out for 8 days.

Figure 3 shows a plot of the overlap comparisons for these series. The differences between overlap comparisons obtained with different TDRS-E geopotential models is again insignificant. The average gain in consistency

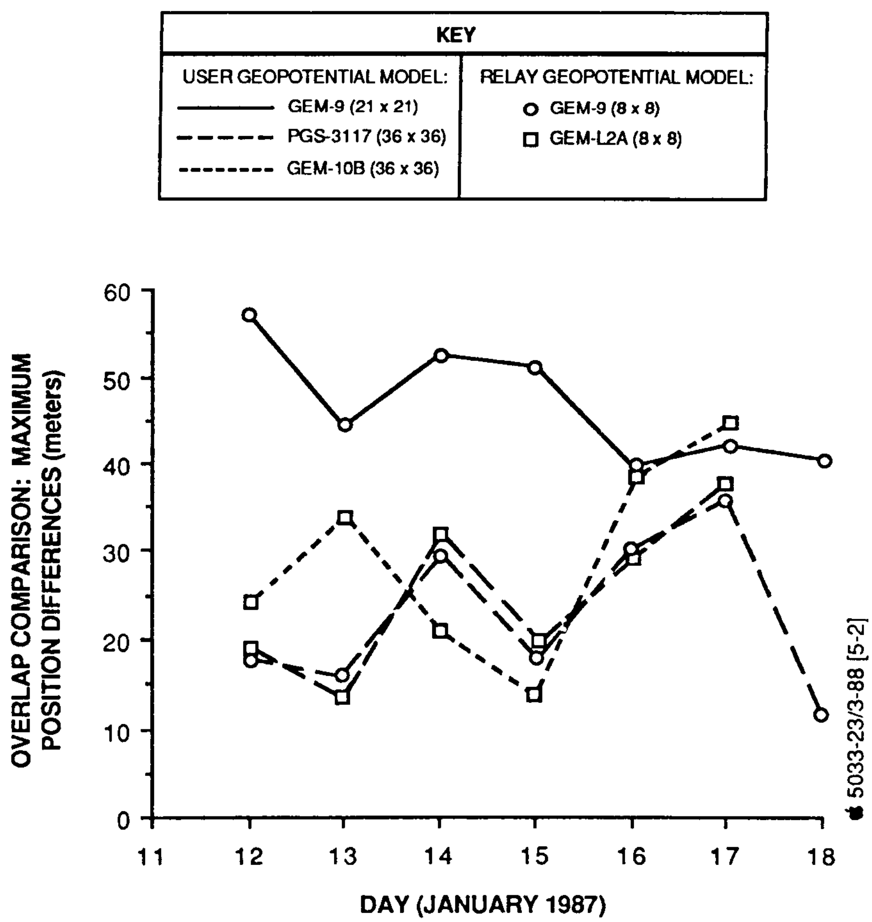

Figure 3. Maximum Overlap Comparisons for ERBS87

relative to GEM-9 (21 x 21) is 18.5 ± 7.1 meters for GEM-10B (36 x 36) and 22.6 ± 5.4 meters for PGS-3117 (36 x 36) [both calculated using six overlaps and the GEM-L2A (8 x 8) model for the TDRS-E orbits].

The improvements in consistency obtained from using the larger potential models in the ERBS87 study is more pronounced than in the other studies. The difference, if it is fair to compare results from different years, comes from degraded consistency of the GEM-9 (21 x 21) orbits (47.8 meters average) relative to the ERBS85 and ERBS86 studies (27.3 meters average), rather than from improved consistency of the orbits obtained with the 36-by-36 models. The degradation is rather consistent throughout the ERBS87 week, which suggests that it is not a random variation. A likely explanation is that the exclusion of GSTDN data in the ERBS87 solutions degrades the consistency of GEM-9 (21 x 21) orbit solutions more than it does the consistency of the PGS-3117 (36 x 36) and GEM-10B (36 x 36) solutions.

3.4 ERBS RESULTS WITH DATA DISTRIBUTION SUBSETS

The GEM-9 (21 x 21) and PGS-3117 (36 x 36) studies of ERBS87 were repeated with two other data distributions consisting of subsets of the available two-way TDRSS tracking data. For these additional studies, the TDRS-E orbits were estimated with the GEM-9 (8 x 8) model. The full data distribution, called dd1, is described in Table 3. Data distribution dd2, nominally a four-pass-per-day tracking schedule, was obtained by deleting approximately every other whole pass. Data distribution dd3 was obtained by shortening every individual tracking pass in dd1 to exactly 5 minutes of valid data (from an average of 20 minutes). The dd2 data distribution consisted of 3.7 passes per day, and the DC editing accepted an average of 579 range and 539 Doppler observations per 34-hour arc. The dd3 data distribution consisted of 7.5 passes per day, and the DC editing accepted an average of 314 range and 315 Doppler observations per 34-hour arc.

The overlap comparisons resulting from the six series using each of three data distributions with each of two geopotential models are plotted in Figure 4 and statistically summarized in Table 5. As expected from the previously described ERBS87 results, the consistency obtained with the PGS-3117 (36 x 36) model is better for all these data distributions than that obtained with the GEM-9 (21 x 21) model. Furthermore, consistency is more seriously degraded by restricting the tracking data coverage with GEM-9 (21 x 21) than with PGS-3117 (36 x 36).

Thirty-four-hour definitive parallel comparisons were performed between the ephemerides for corresponding arcs with different data distributions. Such comparisons quantify the sensitivity of orbit determination results to data selection variation. Both the dd2 and dd3 data distributions were compared with the dd1 distribution. The maximum position differences from these parallel comparisons are plotted in Figure 5 and are statistically summarized in Table 6. On 4 of the 8 days, orbits determined with the GEM-9 (21 x 21) model are markedly more sensitive to the difference between dd1 and dd2 data selections than those determined with the PGS-3117 (36 x 36) model. The results for data distribution dd3 do not strongly differentiate between the two geopotential models used.

4. CONCLUSIONS

The 36-by-36 Goddard geopotential models produced generally better orbit determination consistency for the user spacecraft than did the GEM-9 (21 x 21) model in three out of four studies. For the GEM-10B (36 x 36) model, the average gain in consistency for 18 ERBS overlap comparisons in three studies was 7.4 ± 5.0 meters, resulting in an average consistency of 26.7 meters. The average gain in consistency for the one Landsat-5 study was 7.2 ± 9.5 meters, resulting in an average consistency of 49.2 meters. The PGS-3117 (36 x 36) model, in the one ERBS study in which it was used, improved the consistency by an average of 22.6 ± 5.4 meters, to the 26-meter

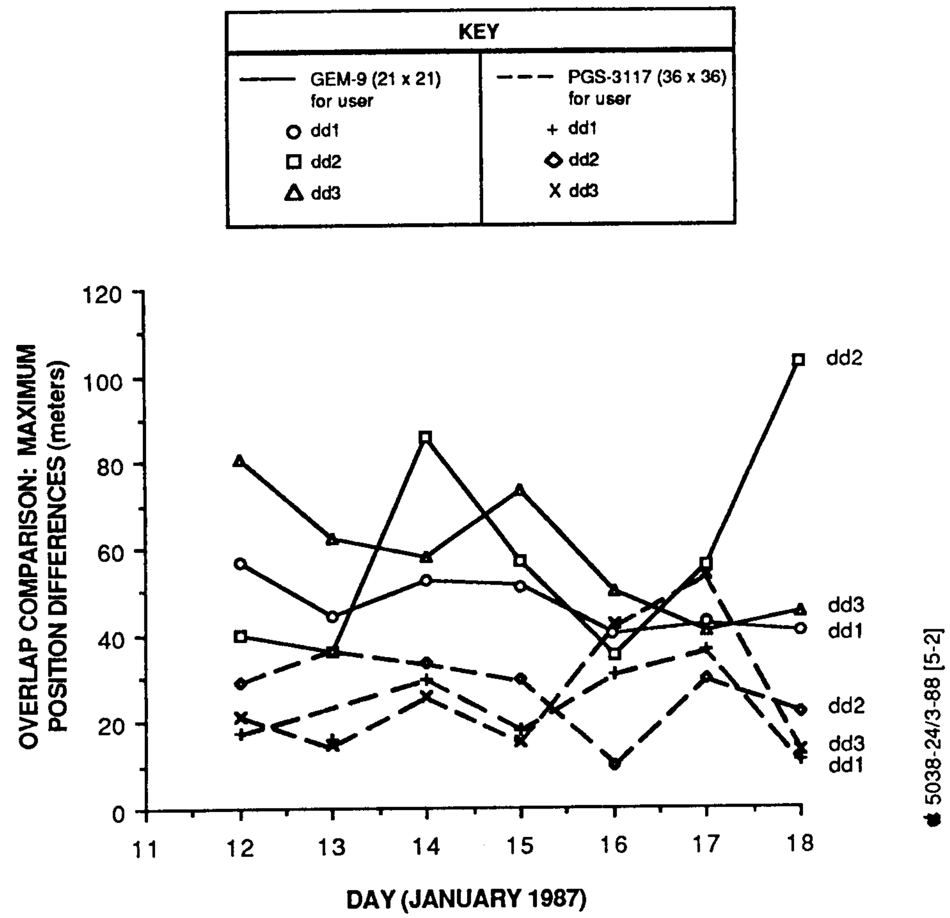

Figure 4. Maximum Overlap Comparisons for ERBS87 With Variable Data Distributions

Table 5. Summary Statistics for ERBS87 Overlap Comparisons With Variable Data Distributions

GEOPOTENTIAL MODEL	DATA DISTRIBUTION	OVERLAP COMPARISON: MAXIMUM POSITION DIFFERENCE (meters)			
		MEAN	STANDARD DEVIATION	MAXIMUM	MINIMUM
GEM-9 (21 x 21)	dd1	46.77	6.23	56.90	39.78
GEM-9 (21 x 21)	dd2	58.76	24.24	102.68	34.75
GEM-9 (21 x 21)	dd3	58.29	13.77	80.68	40.11
PGS-3117 (36 x 36)	dd1	22.64	8.72	36.20	10.77
PGS-3117 (36 x 36)	dd2	26.94	8.11	35.89	9.82
PGS-3117 (36 x 36)	dd3	26.42	14.41	53.55	13.05

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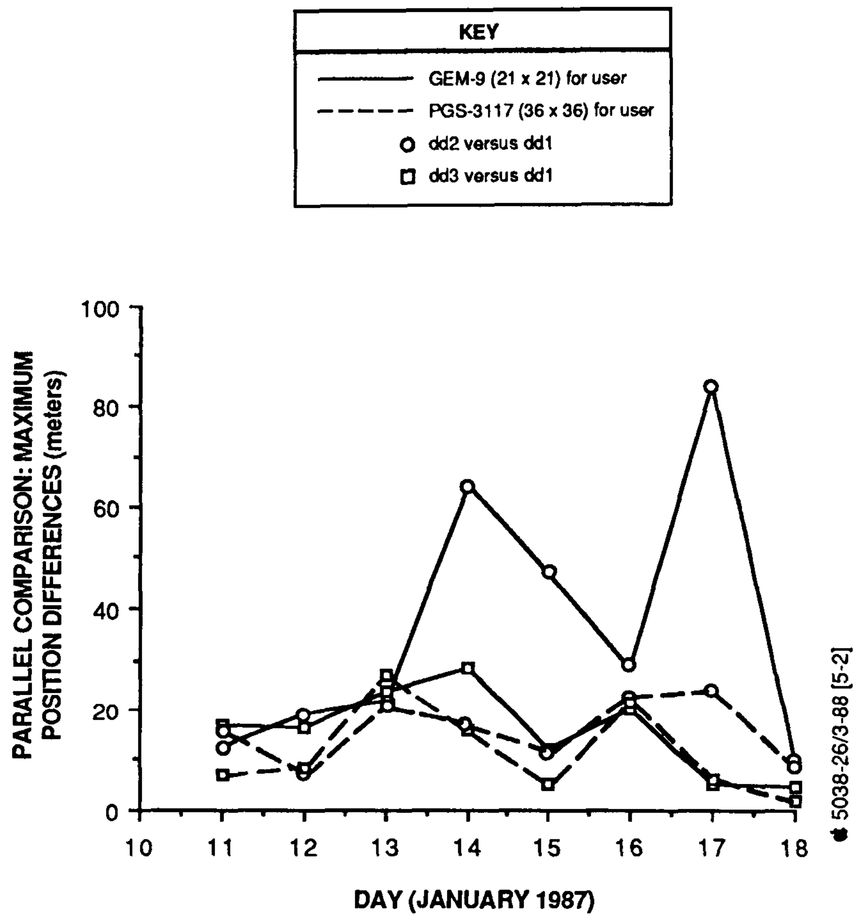

Figure 5. Parallel Comparisons Between ERBS87 Solutions With Different Data Distributions

Table 6. Summary Statistics for Parallel Comparisons Between ERBS87 Solutions With Different Data Distributions

GEOPOTENTIAL MODEL	DATA DISTRIBUTIONS COMPARED	PARALLEL COMPARISON: MAXIMUM POSITION DIFFERENCE (meters)			
		MEAN	STANDARD DEVIATION	MAXIMUM	MINIMUM
GEM-9 (21 x 21)	dd1 VERSUS dd2	35.88	25.06	84.11	9.78
GEM-9 (21 x 21)	dd1 VERSUS dd3	15.84	7.83	28.34	4.81
PGS-3117 (36 x 36)	dd1 VERSUS dd2	15.95	6.02	23.96	7.45
PGS-3117 (36 x 36)	dd1 VERSUS dd3	11.53	8.35	27.06	1.87

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level, performing slightly better than the GEM-10B (36 x 36) model (by 4.1 ± 4.5 meters in the average overlap comparison). There is, however, no clear indication of superiority of either of the 36-by-36 models studied over the other.

The overall average improvement in overlap comparison consistency, which is 7.4 ± 4.3 meters, can be considered significant. The ERBS87 study is the only one of the four in which the decrease in overlap comparisons, from GEM-9 (21 x 21) results to GEM-10B (36 x 36) or PGS-3117 (36 x 36) results, is consistent across the period of study. The results of the ERBS87 study alone demonstrate that, if it is required to achieve and maintain orbit determination consistency better than 40 meters, GEM-9 (21 x 21) must be improved upon and that GEM-10B (36 x 36) and/or PGS-3117 (36 x 36) can support such requirements.

The superiority of the 36-by-36 gravity models becomes more evident as the data complement becomes more restricted. The experiments with data distribution show that the overall consistency obtained with the PGS-3117 (36 x 36) model degrades less rapidly with tracking coverage than does that obtained with the GEM-9 (21 x 21) model. Furthermore, it is a reasonable conjecture that the decrease in consistency of GEM-9 (21 x 21) solutions in the ERBS87 study relative to the ERBS85 and ERBS86 studies, which leaves the other gravity models clearly superior, is due to the exclusion of GSTDN data.

Varying the tracking coverage appears to be an effective means of evaluating gravity models for operational orbit determination. The superiority of the PGS-3117 (36 x 36) model over the GEM-9 (21 x 21) model, shown in the overlap comparisons in the ERBS87 study (with full data), is strongly confirmed by the superior consistency that was observed with respect to deletion of tracking passes. This technique may also prove useful for comparative evaluation of other variations in orbit determination techniques.

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